

THE DESIGN AND IMPLEMENTATION OF A PRACTICAL TSUNAMI EVACUATION DRILL

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SUMMARY:

Tsunami evacuation measures are now an urgent issue in Japanese coastal area. One of important actions for the mitigating damages is the evacuation drill. However past tsunami evacuation drills mostly have not been supposed seismic disaster damage condition. Though, after big earthquake, residents in tsunami inundation estimated area might be needed to evacuate any safety zone in the situation of any damages attacked by seismic motion. Therefore, a practical evacuation drill was carried out in Kuroe and Funoo district of Kainan City. This area is the tsunami inundation estimated area against the Nankai Earthquake. In the evacuation drill, it was assumed that some roads and evacuation sites were blocked, and there were injured persons and vulnerable people. This paper examined regional evacuation problems and residents' perceptions of these risks and the evacuation drill. The possibility and problems of the evacuation drill was also discussed.

Keywords: Evacuation drill, assumed disaster condition, tsunami, Nankai Earthquake, Kainan City

1. INTRODUCTION

Tsunami evacuation measures are currently an urgent issue in Japanese coastal area. One of important actions for the mitigating damages is evacuation drill. However past tsunami evacuation drills mostly have not been supposed seismic disaster damage condition. Though, after big earthquake, residents in tsunami inundation estimated area have to escape to any safety zone in the situation of any damages attacked by seismic motion. This situation must be considered for tsunami evacuation measures.

The national Tsunami Hazard Mitigation Program (NTHMP) pointed out the importance of tsunami education system and evacuation exercise. As to programs, the NTHMP have been implemented activities of disaster reduction education and assessments (Dengler L., 2005). In Indonesia, many programs for damage reduction have been acted especially after 2004 Sumatra Earthquake (Morin J. et al, 2008). And also, there are some tsunami education programs in Japan. On the other hand, ways of these educational programs and evacuation drills are needed to develop to more efficient activities.

The objectives of this study are to examine the ways of evacuation drill design and regional tsunami evacuation strategy problems based on practical evacuation drill. The practical evacuation drill was carried out in Kuroe-Funoo district of Kainan City in Japan where was the tsunami inundation estimated area. Based on the implementation, the effect, possibility and problems of the activities are also discussed.

2. GENERAL DESCRIPTION OF RESEARCH AREA

2.1. Location and Regional Composition

Kuroe-Funoo district is in Wakayama Prefecture and in front of Seto inland sea of Japan (Figure 1). This district is densely built up area and there are many narrow roads. The condition of Kuroe-Funoo district is shown in Fig. 2.

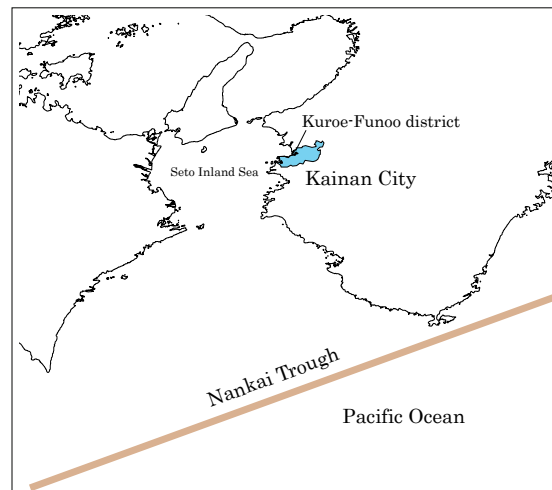


Figure 1. Location of Kuroe-Funoo district and Kainan City



Figure 2. Scenes of Kuro-Funoo district

Table 1. The number of population and household in Kuroe-Funoo District

Population	5885
The number of Households	2591
the rate of aging	36.6% (2151 persons)

The number of population and households are shown in Table 1. The rate of aging (65 years old and over) was high (36.6%). Empty houses are now correlatively increasing. These are important problems in this district.

2.2. Regional Environment against Nankai Earthquake

This area is tsunami inundation estimated area against Nankai Earthquake which is known as a big earthquake repetitively occurring at Nankai trough. Showa Nankai earthquake (1946) struck Kii peninsula. A death toll of 20 and missing persons of 3 in Kainan City were occurred by its seismic motions and tsunami. The damage of Kuroe-Funoo district was especially severe. The scale of next Nankai Earthquake is forecasted higher than Showa Nankai Earthquake. And the occurring of next Nankai Earthquake is estimated in early twenty one century.

It is forecasted as the intensity of 6 on the Japanese scale, tsunami height of 4.5m, and tsunami arrival time of 50 minutes in Kainan City on the Nankai Earthquake damage assessment. Large area in Kuroe-Funoo district is estimated as the inundation of over 2.0m. And there are many damage potential zones of landslide disaster (Figure 3). So, after occurring of Nankai Earthquake, it is evaluated that there are many buried and injury persons by the collapsed building, many impassable roads by collapsed buildings and damaged facilities, and unusable evacuation sites by landslides. In the estimated situation, then, residents in the assumed inundation area must evacuate to any safety zone under impending tsunami arrival.

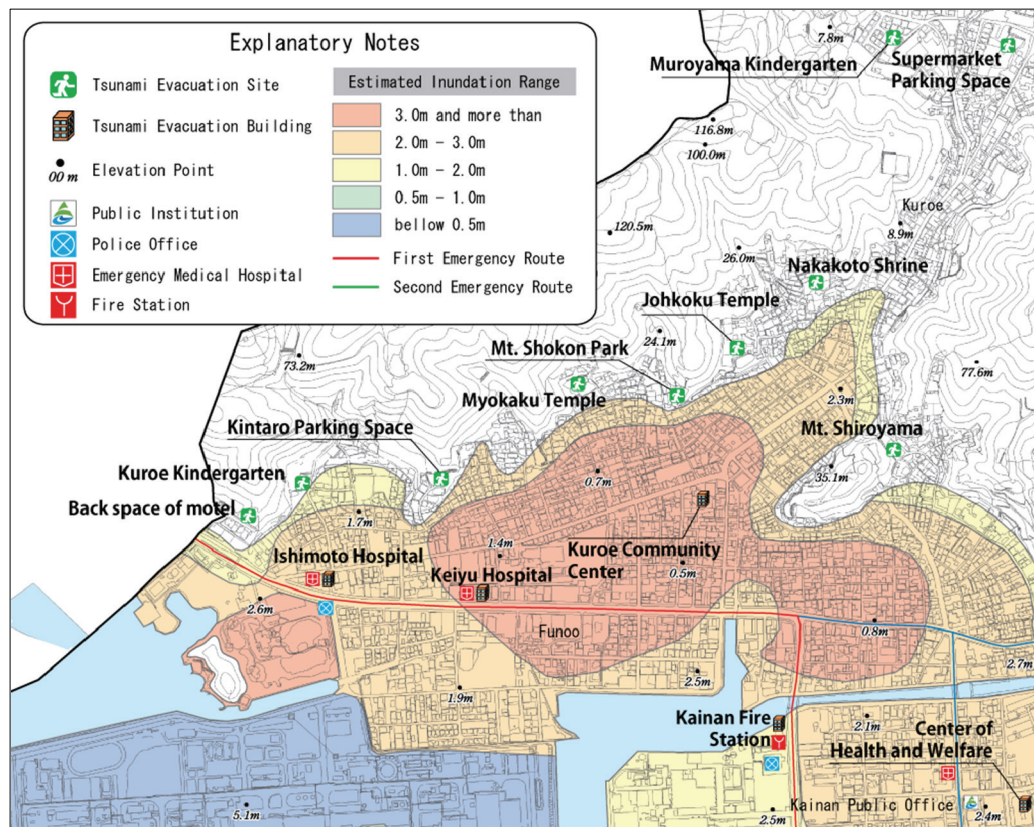


Figure 3. Hazard mapping of Kuroe-Funoo district

2.3. Issues of disaster response

Until the beginning of 2010 year, evacuation site against tsunami had been decided on each neighborhood association in Kuroe-Funoo district. Though, responses and ways of tsunami evacuation were not deeply discussed. Residents' perceptions and motivations for disaster reduction varied widely. So, if the estimated Nankai Earthquake happened, there was large possibility that many victims occurred. It is important for the damage reduction that comprehensive earthquake disaster measures including tsunami evacuation response are examined, and residents have common recognition of Nankai Earthquake risk.

3. DISCUSSION PROCESS OF TSUNAMI EVACUATION PLANNING

In Kuroe-Funoo district, evacuation drill had previously been implemented. However these evacuation drills were only to move to evacuation sites after supposed signals. Accordingly, acting the practical evacuation drill was decided in 2010 year. The evacuation drill has the contents that assumed the situation after big earthquake. This evacuation drill aimed to find out any problems for the evacuation measures and to increase awareness of disaster reduction measures.

Making evacuation planning and drill planning was acted by residents in Kuroe-Funoo district, officials of Kainan City local government, Wakayama Prefecture government, officials of fire service, officials concerned to police office, and expert of disaster reduction measures. Workshops of three times were convened until the evacuation drill. The discussion process of these workshop series are shown in Table 2. Thirty to forty persons took part in each workshop and examined problems in each workshop (Figure 4).

Table 2. The process of making evacuation plan

schedule	Purposes	Contents
First meeting (2010.07.22)	i) To pick up regional problems of tsunami evacuation ii) to gather items of practical evacuation drill	I) Lecture of Nankai Earthquake assessment and regional risk II) Examination of the problems and damages after big earthquake III) Examination of contents of practical evacuation drill
Second meeting (2010.08.23)	i) To pick up high risk points for seismic motion in the district ii) To arrange role sharing of the drill	I) Examination of hazardous places and points based on the hazard map II) Check of the hopeful role on the evacuation drill
Third meeting (2010.09.01)	i) To confirm rules and each role of the evacuation drill	I) Acquirement of evacuation drill contents and each role as the staff

**Figure 4.** Workshop scenes

4. CONTENTS OF TSUNAMI EVACUATION PLAN

Based on these discussion and preparation, this practical evacuation drill was carried out on 5th September 2010 in Kuroe-Funoo district. Table 3 and Fig. 5 show contents of estimated earthquake occurring and estimated damage situations of the drill.

In the evacuation drill, it was also assumed that some roads and evacuation sites were blocked, and there were injured persons and vulnerable people. The ways of evacuation drill was in advance informed to residents, although the setting detail situation was not informed. The number of participants on the drill was approximately 1000 persons. Scenes of the practical evacuation drill appear in Fig. 6.

Table 3. assumed situations and information contents of the tsunami evacuation drill

<u>Assumed Situations</u> Tokai-Tonankai-Nankai Earthquake occurring Time: 5 th , September, 2010 (Saturday) Magnitude: 8.6 Seismic intensity: upper 5 to 6 lower Maximum tsunami height: 5.9m
<u>Announcement</u> 08:00: signal of starting the evacuation drill 08:02: earthquake prompt report 08:03: major tsunami warning 08:13: major tsunami warning 08:23: major tsunami warning 08:50: arrival of major tsunami 09:00: signal of finishing the evacuation drill

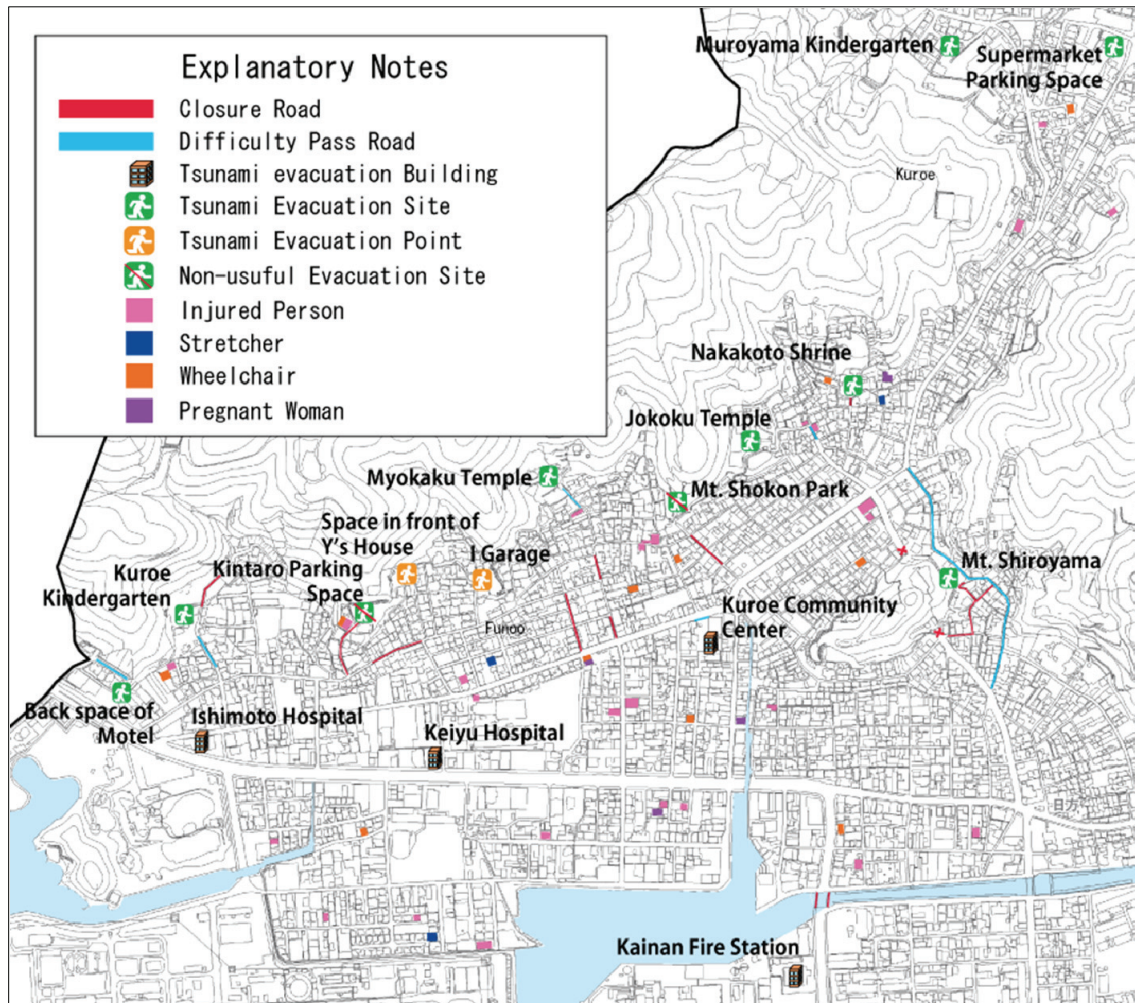


Figure 5. Situation of the practical evacuation drill



Figure 6. The Evacuation Drill Scenes

5. SURVEY METHOD

While the evacuation drill acted, questionnaire survey was carried out for the participants. The purpose of this survey is to see the evacuation behaviors and perceptions of participants. In the investigation, the questionnaire was distributed to participants on each evacuation site, after participants arrived at the site, and asked to enter the questionnaire on the site. In this regard, the arrival time was filled by the staff. The number of valid response was 579 samples. The attribute of respondents is showed in

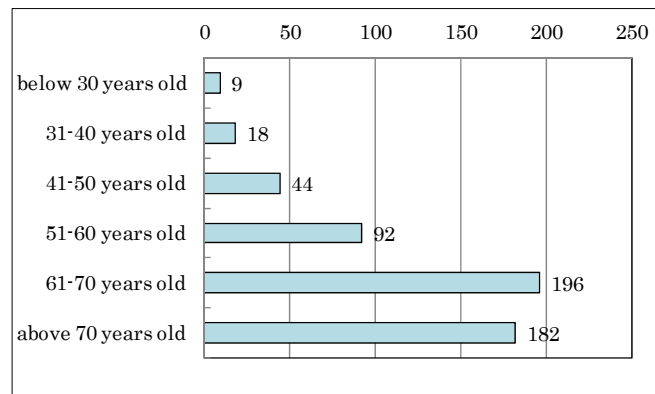


Figure 7. Respondents' Attribute

Fig. 7.

6. EVACUATION BEHAVIORS IN THE DRILLS' SITUATION

6.1. The difference between this drill's evacuation site and advanced supposed evacuation site

Evacuation sites of Kuroe-Funoo district in the drill was 16 sites. This evacuation drill set unusual sites of two, Kintaro parking space and Mt.Shokon park for the reason of landslide (see Fig. 5).

Fig. 8 is the result of the difference between this drill's evacuation site and advanced supposed evacuation site of respondents. In this question item, the difference between actual evacuation site and supposed evacuation site in the drill's starting time was queried.

Fig. 8 shows that high ratio evacuation sites of "different" were Kuroe community center building and Kuroe kindergarten. On the "Kuroe Kindergarten", the reason was that Kintaro parking space, near the Kuroe Kindergarten, closed in this practical drill. On the other hand, the reason that the participants gathered Kuroe community center building is presumed that they couldn't use their estimated evacuation site, they gave up to arrive the evacuation site by some block point, this building was on the way of their estimated evacuation site, or this building was recognized as the site of the center area of Kuroe-Funoo district.

6.2. Difference between ordinal travel time and this drill's travel time

The difference between the mean of ordinal travel time and the drill's travel time is shown in Fig. 9.

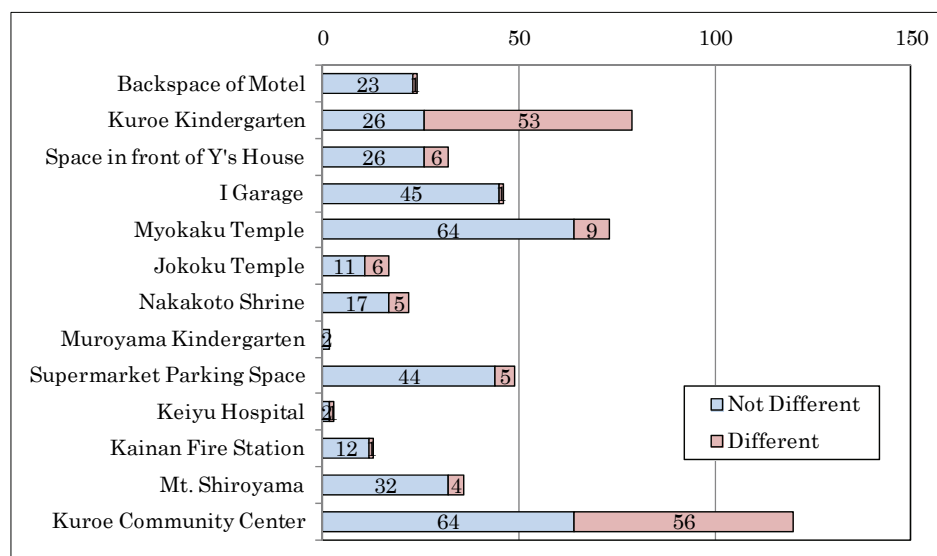


Figure 8. Results of the difference for the estimated evacuation site

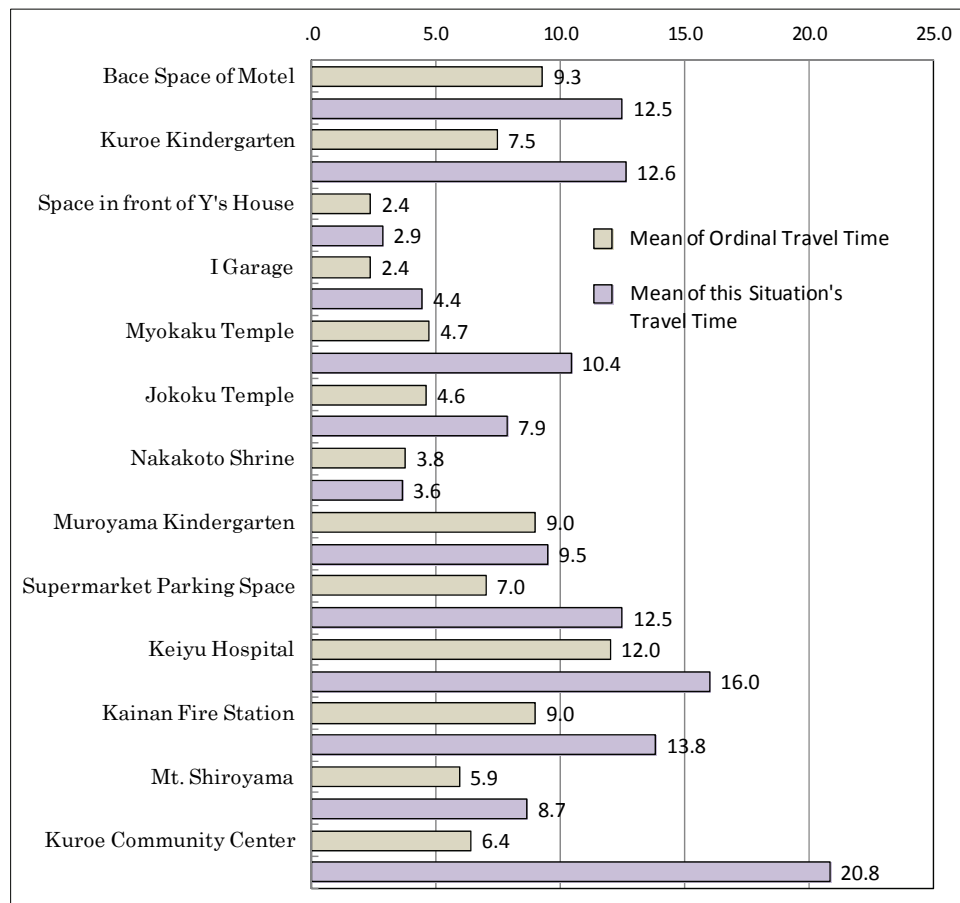


Figure 9. the relationship between the ordinal travel times and this drill's travel time

The numbers in parentheses of Fig. 9 are standard deviation and maximum value of each evacuation site. On the measurement of travel time, ordinal travel time was based on the result of the respondent's sense for travel time between respondents' home and supposed evacuation site under the normal situation. The travel time under this drill situation was the result of the time difference between the departure time and arrival time.

Fig. 9 shows that the maximum difference between the ordinary travel time and this drills' travel time was Kuroe community center building. As already mentioned, in Kuroe community center building, many participants didn't suppose previously to move to the site. So it is speculated that the travel time to Kuroe community center building was required. And also, Fig. 9 summarizes that travel times of any evacuation sites were longer than ordinary times

7. THE AWARENESS OF EARTHQUAKE AND TSUNAMI RISKS

7.1. Risk perceptions of Nankai Earthquake

In this chapter, risk perceptions of respondents for Nankai Earthquake are examined. These items which are related to risks of Kuroe-Funoo district after Nankai Earthquake occurring are shown in Fig. 10. In the questions, each item was inquired in five scales between 'it would happen' to 'it would not happen'.

The results were that risk perceptions were very high for all question items. '(1) not to be able to move to evacuation site' and '(3) to be many injured persons' were especially recognized of high risk.

7.2. Awareness of tsunami evacuation measures

Fig. 11 shows the result of the awareness related to the necessity for tsunami evacuation measures. On

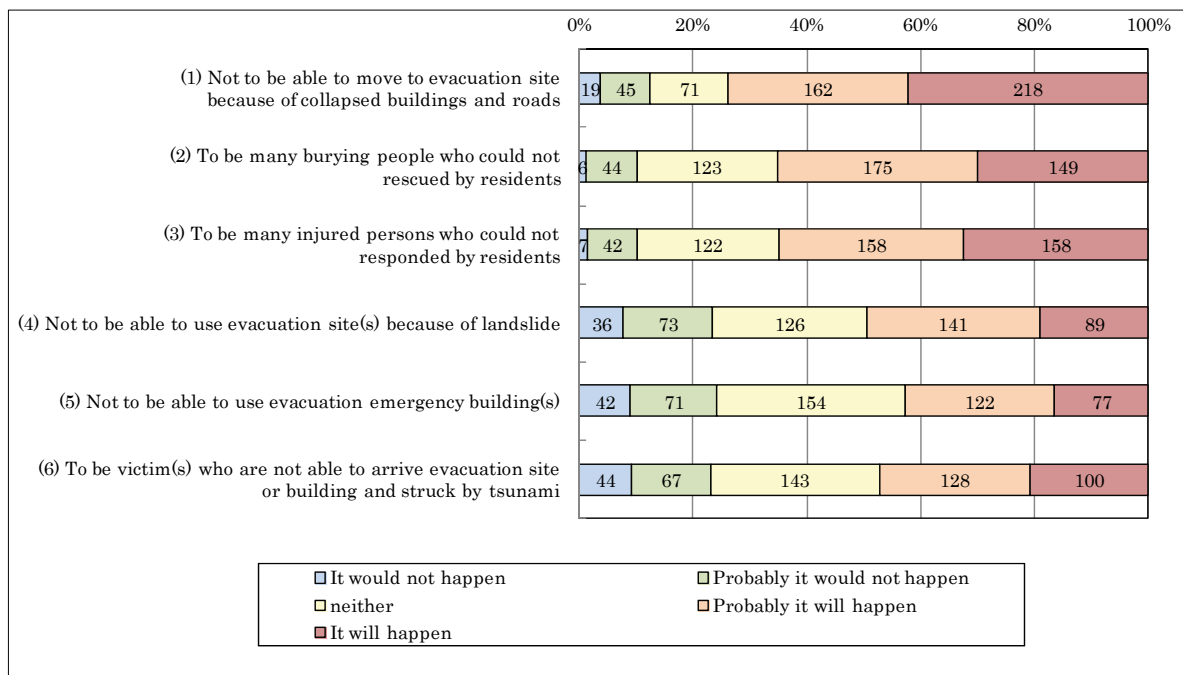


Figure 10. Risk Perceptions of Nankai Earthquake and Tsunami

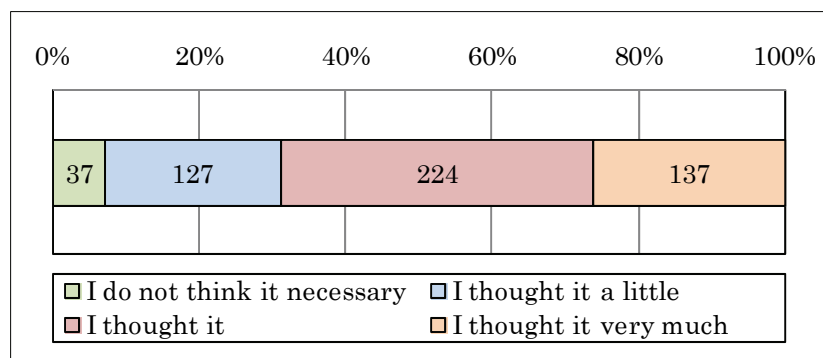


Figure 11. The necessity awareness of tsunami evacuation measures

the question item, the ratio of the necessity awareness associated with the discussion for tsunami evacuation by the participation of this drill was inquired.

In Fig. 11, what the necessity awareness tended to be increased was confirmed. On the other hand, there were a few responses of 'I don't think it necessary'. The large number of these responses was in the evacuation sites where are not in tsunami inundation estimated area on the current hazard map. However there is any tsunami inundation risk even in this area. Increasing of necessity awareness related to these measures is one problem.

Table 4 summarizes results of relationship between the necessity awareness and risk perceptions of Nankai Earthquake. The data for the analysis was made up by the disposition that 'I don't think it necessary' on Fig. 10 was one point, and 'I thing it very much' was five point', and ordinal scale was treated to interval scale. In this analysis, One-way ANOVA was used.

On these analyses, each result indicated that the higher risk perceptions of Nankai Earthquake were the more awareness of necessity for tsunami evacuation measures were increased.

8. DISCUSSION

8.1. The issues based on the practical evacuation drill

On the implementation of the practical evacuation drill, a lot of evacuating problems what was not

Table 4. Relationship between ‘risk perceptions of Nankai Earthquake and tsunami’ and ‘necessity awareness of tsunami evacuation measures’

Item	I do not think it necessary		I thought it a little		I thought it		I thought it very much		Results of One-way ANOVA
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	
(1) Not to be able to move to evacuation site because of collapsed buildings and roads	3.71	1.45	3.84	1.10	4.00	1.02	4.26	1.12	F=4.08 p=0.007
(2) To be many burying people who could not rescued by residents	3.70	1.16	3.61	0.89	3.87	0.95	4.09	1.08	F=4.92 p=0.002
(3) To be many injured persons who could not responded by residents	3.56	1.34	3.61	0.96	3.87	0.94	4.19	1.02	F=7.70 p=0.000
(4) Not to be able to use evacuation site(s) because of landslide	3.07	1.51	3.11	1.04	3.39	1.10	3.68	1.30	F=5.14 p=0.002
(5) Not to be able to use evacuation emergency building(s)	2.69	1.46	3.09	1.03	3.31	1.13	3.51	1.24	F=4.75 p=0.003
(6) To be victim(s) who are not able to arrive evacuation site or building and struck by tsunami	2.36	1.34	3.19	1.07	3.43	1.11	3.68	1.31	F=10.89 p=0.000

appeared in previous drill were found out. The result indicated that; i) the travel time to escape to safety site was longer than ordinal time and some residents were confused if evacuation site or some road were blocked, ii) there is a possibility that a lot of residents concentrated in Kuroe community center as next candidate evacuation point, iii) on the conclusion the evacuees might be exceeded largely than the capacity of Kuroe community center.

Some participants on the drill didn't afford the evacuation time until evaluated tsunami arrival time. However, after actual ocean trench earthquake, residents in damaged area can not immediately start to evacuate, as continuous quake time is long and there are various damages. So constructing of Rapid evacuation active system is important problem in the district.

In the case of tsunami attacking the district, inundating duration continues for some little time. In the occasion, people in evacuation buildings can not go out another area. Considering the duration time, some people might break health in overcrowded situation into Kuroe community center. Therefore comprehensive arrangement of tsunami evacuation rules in the district, especially the second evacuation sites and buildings, not to concentrate a lot of people in same building is needed.

8.2. The possibility and problems of practical evacuation drill

The practical drill in this study is able to be treated as a social experiment of tsunami evacuation. This approach was also one of challenge to appear issues of tsunami evacuation through the social experiment. This evacuation drill actually brought out the issues, and leaded to increase necessity awareness of measures.

However there are a few people of bellow 40 years old in participants of this drill. Increasing these participants is a problem. Discussion of specific disaster reduction measures and ways in region and spread these activities need to cooperate with school educational program.

Repeated activities are important issue on this approach and disaster reduction measures. These activities are able to estimate various occurrence conditions and earthquake damage situation. These repeating activities lead to penetrate into regional residents and have disaster reduction abilities. And also, materials of spatial problems, which are evacuation site and route and so on, are able to be examined based on the evacuation problems.

AKCNOWLEDGEMENTS

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